

# Exercise 15.7

## LeChâtelier's Principle

Name: \_\_\_\_\_

Date: \_\_\_\_\_ Per: \_\_\_\_\_

When a system at equilibrium is exposed to a stress, the system will respond by moving in a direction that reduces the stress and reestablishes equilibrium. Stresses include change in **concentration**, change in **temperature**, and/or change in **volume/pressure** of systems involving gaseous reactants or products. The stress increases the rate of either the forward or reverse reaction temporarily until the counter-reaction can speed up and return the system to equilibrium.

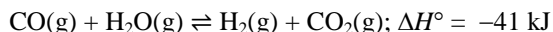
Increases in **concentration** of aqueous or gaseous species in the system will increase collisions of those species and favor the reaction in which they are consumed. Decreases in concentration will reduce collisions and the reaction in which those species are reactants will slow, allowing the counterreaction to become temporarily dominant.

Changes in **volume/pressure** only affect gaseous species in the system as they change the concentration of the gaseous species. Increasing the pressure (decreasing the volume) on a system will increase the concentration of each gas species equally. The result is that the system will move in the direction that produces the fewest gas molecules. Decreases in pressure (increasing the volume) will favor the reaction that produces the greater number of gas particles.

Changes in **temperature** relate to the thermodynamics of the system. Increasing the temperature will favor the endothermic reaction and reducing the temperature will favor the exothermic reaction.

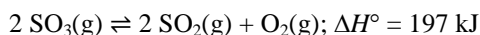
**DIRECTIONS:** Answer each of the following in the space provided.

1. An important reaction in the commercial production of hydrogen is



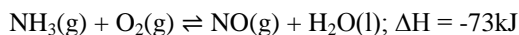
How will this system at equilibrium shift if:

- gaseous carbon dioxide is removed? \_\_\_\_\_
  - the pressure is increase by adding helium gas? \_\_\_\_\_
  - water vapor is added? \_\_\_\_\_
  - the temperature is increased? \_\_\_\_\_
  - the pressure is increased by decreasing the volume of the reaction container? \_\_\_\_\_
2. What will happen to the number of moles of  $\text{SO}_3$  in equilibrium with  $\text{SO}_2$  and  $\text{O}_2$  in the reaction



in each of the following cases?

- Oxygen gas is added. \_\_\_\_\_
  - The pressure is increased by decreasing the volume. \_\_\_\_\_
  - The pressure is increased by adding argon gas. \_\_\_\_\_
  - The temperature is decreased. \_\_\_\_\_
  - A catalyst is added. \_\_\_\_\_
  - Gaseous sulfur dioxide is removed. \_\_\_\_\_
3. Predict the effect on the **UNBALANCED** system at equilibrium for the stresses listed below.



- Increase  $[\text{NH}_3]$  \_\_\_\_\_
  - Increase Pressure \_\_\_\_\_
  - Decrease  $[\text{O}_2]$  \_\_\_\_\_
  - Decrease Heat \_\_\_\_\_
4. How would an increase in pressure affect the  $[\text{H}_2]$  in the following reactions?
- $2 \text{H}_2\text{(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2 \text{H}_2\text{O(g)}$  \_\_\_\_\_
  - $4 \text{H}_2\text{(g)} + \text{Fe}_3\text{O}_4\text{(s)} \rightleftharpoons 3 \text{Fe(s)} + 4 \text{H}_2\text{O(l)}$  \_\_\_\_\_
  - $\text{H}_2\text{(g)} + \text{Cl}_2\text{(g)} \rightleftharpoons 2 \text{HCl(g)}$  \_\_\_\_\_
5. Old-fashioned "smelling salts" consist of ammonium carbonate,  $(\text{NH}_4)_2\text{CO}_3$ . The reaction for the decomposition of ammonium carbonate is  $(\text{NH}_4)_2\text{CO}_3\text{(s)} \leftrightarrow 2\text{NH}_3\text{(g)} + \text{CO}_2\text{(g)} + \text{H}_2\text{O(g)}$  and is endothermic. Would the smell of ammonia increase or decrease as the temperature is increased?

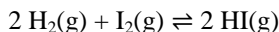
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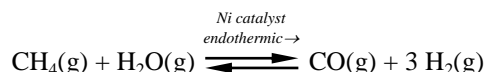
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6. In which direction will the position of the equilibrium be shifted for each of the following changes.



- $\text{H}_2(\text{g})$  is added. \_\_\_\_\_
- $\text{I}_2(\text{g})$  is added. \_\_\_\_\_
- $\text{HI}(\text{g})$  is removed. \_\_\_\_\_
- Some  $\text{Ar}(\text{g})$  is added. \_\_\_\_\_
- The volume of the container is doubled. \_\_\_\_\_
- The temperature is increased. (For  $\text{HI}$ ,  $\Delta H_f = 25.9 \text{ kJ/mol}$ .) \_\_\_\_\_

7. Hydrogen for use in ammonia production is produced by the reaction



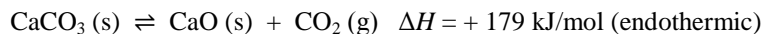
What will happen to a reaction mixture at equilibrium if

- $\text{H}_2\text{O}(\text{g})$  is removed? \_\_\_\_\_
- $\text{CO}(\text{g})$  is removed? \_\_\_\_\_
- an inert gas is added? \_\_\_\_\_
- the temperature is increased? \_\_\_\_\_
- the Ni catalyst is removed? \_\_\_\_\_

8. How would an increase in pressure affect the  $[\text{H}_2]$  in the following reactions?

- $2 \text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{H}_2\text{O}(\text{g})$  \_\_\_\_\_
- $4 \text{H}_2(\text{g}) + \text{Fe}_3\text{O}_4(\text{s}) \rightleftharpoons 3 \text{Fe}(\text{s}) + 4 \text{H}_2\text{O}(\text{l})$  \_\_\_\_\_
- $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2 \text{HCl}(\text{g})$  \_\_\_\_\_

9. Predict the direction the system will shift for each of the following stresses.



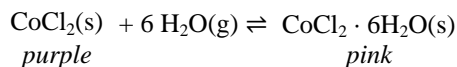
- $\text{CO}_2$  is added to the system. \_\_\_\_\_
- The temperature of the container is decreased. \_\_\_\_\_
- The volume of the container is decreased. \_\_\_\_\_
- The volume of the container is increased. \_\_\_\_\_
- $\text{CaO}$  is removed from the system. \_\_\_\_\_
- $\text{CaCO}_3$  is added to the system. \_\_\_\_\_

10. How does the addition of a catalyst to a system at equilibrium affect the equilibrium position of the system? \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_

11. Given the reaction at equilibrium:  $\text{X}_2(\text{g}) + 2 \text{Y}_2(\text{g}) \leftrightarrow 2 \text{XY}_2(\text{g}) + 80 \text{ kcal}$ , the equilibrium point will shift to the right if the pressure is \_\_\_\_\_ and temperature is \_\_\_\_\_.

12. For a given system at equilibrium, lowering the temperature will always favor the \_\_\_\_\_ reaction.

13. Novelty devices for predicting rain contain cobalt(II) chloride and are based on the following equilibrium:



What color will such an indicator be if rain is imminent? \_\_\_\_\_